5-2009

CONTRACTING IN THE PHARMACEUTICAL INDUSTRY: PREDICTING PAYMENTS IN STRATEGIC ALLIANCES

Jonathan Altman
Clemson University, jaltman@clemson.edu

CONTRACTING IN THE PHARMACEUTICAL INDUSTRY: PREDICTING PAYMENTS IN STRATEGIC ALLIANCES

A Dissertation
Presented to
The Graduate School of
Clemson University

In Partial Fulfillment
of the Requirements for the Degree
Doctor of Philosophy
Economics

---

by
Jonathan Andrew Altman
May 2009

Accepted by:
Michael T. Maloney, Committee Chair
Robert Tollison
John Warner
Raymond Sauer

ABSTRACT

This paper empirically analyzes how circumstances affect the creation of strategic alliances in the pharmaceutical industry, and the form these alliances take. The models introduced in this paper use the cost of capital and monitoring costs to predict the timing of the deal, which in turn allows the prediction of the deal type. The deal type is then used to predict payment types used in the deal. Deals are characterized by five payment types; upfront, royalty, milestone, equity, and research payments. Deals are also characterized by one of five deal types; co-development, license, acquisition, outsource, and asset purchase. Each of these is a response to a specific contracting problem such as cost of acquiring capital and asymmetric information. The payment types used in pharmaceutical alliances are chosen to efficiently produce monitoring or purchase assets in the face of asymmetric information and to maximize firm profits.

ACKNOWLEDGMENTS

I'd like to extend special thanks to Dr. Michael T. Maloney, Dr. Robert Tollison, Dr. John Warner, Dr. Raymond Sauer, and Dr. Charles Thomas of Clemson University for their advice during the creation of this paper.

TABLE OF CONTENTS

LIST OF TABLES

INTRODUCTION

The pharmaceutical industry has exhibited a major shift in business strategy over the past few decades. In the late 1970's, large pharmaceutical firms began relying less on using high-throughput screening of chemical libraries to find treatments for human diseases, and relying more on structure-based drug design. This shift in strategy caused large transition costs for the large pharmaceutical corporations, which were therefore slow to respond to the changes. This created a cost advantage for smaller biotech firms. Small biotech corporations were formed to take advantage of proprietary human capital, and were able to adapt to this new style of biotechnology quickly and cheaply. When larger firms successfully adapted to the transition, they enjoyed economies of scale and scope due to their larger size and access to capital. This created superior efficiency when compared to the smaller firms. The larger firms then merged with or acquired some smaller firms in order to more efficiently use any proprietary information or pipeline held by the smaller firm (Galambos & Sturchio, 1998). In other cases, firms formed alliances to co-develop specific drugs or technologies, which took advantage of the smaller firm's research efficiency, and the larger firm's low cost of capital. This paper uses data collected from press releases to explore the makeup of pharmaceutical deals between large pharmaceutical firms, smaller pharmaceutical firms called biotechs, and universities. The model predicts the timing of alliances from the size of the firms involved, and then predicts the type of deal and payments from the timing of the deal.

PRIOR RESEARCH

The following is a review of works on contracting in the pharmaceutical industry. The prior research in this area focuses on the cost advantages and nature of the industry which make strategic alliances profitable, and the effects of these alliances after being undertaken.

Galambos and Sturchio (1998) review the transition from pharmaceutical companies to the strategic alliances of large pharmaceutical and small biotechnology firms. The authors of this paper suggest that biotechnology firms were able to prosper due to transitions costs of big pharmaceutical firms when transitioning from chemical to biological formulation of drugs. Originally, there was a random search of chemicals by pharmaceutical firms to find useable medicines. As technology improved, specific problems could be solved based on more advanced knowledge of biology. This created an opportunity for scientists to create new firms with proprietary human capital as the larger pharmaceutical firms transitioned to biotechnology. The large pharmaceutical firms invested heavily in biotechnology in the 1970s and 80s and integrated with biotechnology firms to increase their knowledge base. The paper by Galambos and Sturchio presents a background for the further examination of strategic alliances as a profit maximizing technique.

Arora and Gambardella (1990), examine the complementarity of agreements between firms, research agreements with universities, investments in the capital stock of biotechs,

and acquisition of biotechs. The authors conclude that the foundation for the agreements between large and small pharmaceutical firms is the acquisition of some rights to a specific downstream product or technology. In many cases, biotechs emerge only to exploit a specific technology and have no intention of long term or broader research goals. The research agreements between pharmaceutical firms and universities are based on acquiring the use of basic scientific knowledge from the university. Acquisitions are used to acquire the proprietary technologies of some smaller companies or to quickly add a new sector to the larger firm's knowledge base.

Arora and Gambardella claim that investment in equity is an attempt of the large firm to gain favor of the small firm in current and future rights to information and product licensing. An investment in equity may also be a way of acquiring familiarity with the work of the biotech. This investment in knowledge and repeat formal agreements may prevent moral hazard. The strategies listed above each target a specific goal of the large firm to acquire tangible or intangible assets to increase efficiency and productivity of their firm. They are therefore complementary, such that large firms may use each strategy in combination towards a specific goal while these strategies do not seem to necessarily be substitutes or work against one another.

My paper builds on the work done by Arora and Gambardella in the area of acquisitions of small biotechs with propriety information. However, I disagree with their implication that firms will create alliances with another firm simply to learn about the firm, or to gain

favor with the firm through repeated dealings. It is my hypothesis that firms will seek to maximize profits regardless of previous deals. Profits will be maximized by dealing with the low cost producer of capital or research.

Arora, Ashish, and Gambardella (2005) claim that bigger companies gain knowledge about the smaller company by investing in equity. Again, this does agree with my hypothesis that firms seek to maximize profits based on low cost production. These authors suspect that by being a shareholder, they are privy to insider information on the company, can keep track of it, and be more likely to capture deals. Information on public companies is publicly available, and information on private companies should be made available to potential investors in order to maximize the opportunities of the private firm. Using an investor's capital to buy equity in the firm being researched has a high opportunity cost associated with it, since this capital can no longer be used to invest elsewhere.

In the case that it is a privately held firm, or the client is researching several firms, information can more cheaply be obtained from firms that specialize in gather that data, such as recap.com, medtrack.com, datamonitor.com. This prevents repeated search costs and therefore lowers overall costs of searching. Information on a firm may also be obtained by researching the other deals that a firm has made (Nicholson 2005). The information available through diligent research should be at a quality as high as information obtained by a firm that has an equity interest in the firm being researched. If

this is not the case, then there is asymmetric information, which suggests inefficiency in the market.

Arora, Ashish, and Gambardella go on to claim that an investor in a firm will be more likely to benefit from economies of scope, since there will be sharing of research information. There is no reason to believe that there will be knowledge sharing between firms that is not specific to a contract unless the client firm acquires controlling interest in the research firm, as in acquisitions. The benefits from all shared knowledge are therefore captured in the contract with no extra, uncontracted knowledge sharing between firms. There may, however, be knowledge spillovers within a firm due to the acquisition of new technologies.

Danzon, Nicholson, and Pereira, wrote *Productivity in Pharmaceutical-Biotechnology R&D: The Role of Experience and Alliances* (2003) to develop the idea of the value of having experience of forming and undertaking alliances. Their results suggest that returns to investment vary significantly according to therapeutic category, and products which are developed in alliances during phase 2 and 3 testing are more likely to be successful, especially when the licensee is large. The authors go on to develop the idea that alliances can be a way of obtaining experience in an area. Some firms may be taking on these deals in order to increase the value of the firm or the value of their services in the future. This hypothesis is supported by the finding that phase 2 testing is more likely to be successful if developed with therapeutic category specific experience and by firms with

specific rather than general experience. The authors' data is acquired from ADIS international and Windover.

The paper by Danzon, Nicholson, and Periera is useful in my research as support for the hypothesis that later deals are associated with less risk of failure. Less risk of failure leads to the prediction that the total payment will be larger, ceteris paribus, and payment types will be chosen with less concentration on the reduction of monitoring costs.

Danzon, Epstein, and Nicholson, discuss the combination of firms in *Mergers and Acquisitions in the Pharmaceutical and Biotech Industries* (2004). This research is a starting point for the explanation of the observed trend in acquisitions in my paper. The authors show that "mergers are a response to excess capacity due to anticipated patent expirations and gaps in a company's product pipeline." For large firms, a gap in the product pipeline means that human and physical capital are not being used efficiently. When faced with an empty pipeline, a pharmaceutical corporation could reduce staff and sell assets to avoid merging. This would involve the loss of quasi rents from investment in human and physical capital (Oi, 1962). By buying another firm's pipeline through merging or acquiring that firm, the purchasing firm can utilize their resources more efficiently. Acquisition is therefore a mechanism to transfer assets to more efficient uses or management, and may be cheaper than attempting to create them in-house. For the smaller firm being merged or acquired, the merger is an exit strategy. Small firms, defined here as greater than $20 million in sales, but less than $1 billion in enterprise

value have the propensity to be acquired if they are financially weak. Financially strong firms are more likely not to engage in M&A at all.

Merged firms had slower growth than similar, unmerged, firms in the third year following a merger, showing that although merging is a response to distress, it may not be a solution. Small firms that merge have slower R&D growth than similar firms, suggesting that integration may divert cash from R&D. Horizontal mergers are rationalized on the basis of the research intensity undertaken by the pharmaceutical industry, which averages R&D to sales ratio of 18% compared to 4% for the US manufacturing industry overall (PhRMA).

Nicholson, Danzon, and McCullough continue the development of the idea of alliances building firm value and evaluate the possibility of asymmetric information in the market for pharmaceutical alliances in *Biotech-Pharmaceutical Alliances as a Signal of Asset and Firm Quality* (2005). Asymmetric information will affect market valuation of firms. The authors examine whether drugs developed in an alliance are more likely to succeed, or whether there is a lemons problem. The lemons problem (Pisano, 1997) suggests that the less successful drugs are out-licensed due to asymmetric information between pharmaceutical firms. The data, however, does not support this. In 1998, biotechs raised three times as much from alliances with pharmaceutical companies ($6.2 billion) as from the private and public equity markets combined. This supports the hypothesis maintained

in my paper, which states that deals are not made in order to sell off failing products, but rather to take advantage of comparative advantage.

The analysis finds that biotech firms receive a 47% discount on their first deal relative to firms that have signed at least two prior deals, and 28% on the second deal. This discount is not consistent with the post deal performance of the drug. The authors therefore reject the lemons hypothesis. The discount is due to asymmetric information and making this deal, despite the discount, is valuable to the biotech because it signals value to the financial market, and increases the value of subsequent deals. The authors therefore find that there is value to the biotech of signaling to the financial market, but since experienced biotechs continue to make alliances, there must also be some advantage due to comparative advantage of different sized firms.

Aghion and Tirole wrote *The Management of Innovation* (1994) which discusses the cost of capital as it applies to highly human capital intensive industries. They find that firms in industries that require large amounts of human capital relative to physical and financial capital will have research performed by independent units. Each aspect of production can be performed by the firm with the comparative advantage, creating high competition among researchers. This theory of comparative advantage and specialization due to cost of capital and ownership of human capital is the foundation for creating a strategic alliance in my paper.

Lerner and Merges wrote *The control of Technology Alliances: An Empirical Analysis of the Biotechnology Industry* (1998), to test the Aghion- Tirole theory that the researcher's control will be positively correlated with the researcher's financial resources in the biotechnology industry. This paper uses three case studies and a quantitative analysis of 200 alliances. The authors find that it is the researcher's financial condition rather than the interest of maximizing joint value. This supports the Aghion and Tirole theory that control will be positively correlated with researcher's financial capital.

Civan and Maloney seek to support their theory that drug development responds to consumer demand in their paper *The Determinants of Pharmaceutical Research and Development Investments* (2006). These authors find that characteristics of the disease other than demand for the drug in the United States does not motivate the production of research and development of drugs. Changes in policy that affect demand or quantity demanded or supplied of drugs in the U.S. will affect drug development, and could reduce the amount of drug development. Allowing the importation of drugs from other countries at lower prices could be detrimental to drug development.

Civan and Maloney continue the development of their hypothesis by testing the effect of prices of existing drugs on the number of drugs in the development pipeline in *The Effect of Price on Pharmaceutical R&D* (2007). The authors found a significant positive correlation between prices and number of drugs in pipeline. As cheaper drugs are imported to the United States from other countries, either as a patent infringement or due

to price discrimination, the drug pipeline will suffer. By looking at changes in prices of drugs and pipeline drugs in specific disease markets, the authors find the elasticity of supply of pipeline drugs to be between 28 and 49%. The authors therefore suggest that a higher market price of drugs increases incentive to produce research and development, and so the pharmaceutical market faces and upward sloping supply curve for research and development. My paper discusses the falling costs of producing research due to alliances with biotechs which have a comparative advantage in early stage development. The papers by Civan and Maloney support the theory that alliances are necessary to maintain competitiveness in the market.

Grabowski and Vernon claim in *Consumer Protection Regulation in Ethical Drugs* (1977), that part of the cause of the shrinking number of pharmaceutical firms in the US is that the more stringent regulation on the US pharmaceutical market is creating a barrier to entry. This paper was written in 1977 before the biotech boom.

Grabowski, Vernon, and Thomas wrote Estimating *the Effects of Regulation on Innovation: an International Comparative Analysis of the Pharmaceutical Industry* (1978), and show that while R&D expenditures increase, new drug introductions (including only new chemical entities, not new dosages or new brand names) decreased. Possible causes of this are listed as;

1. Increased regulation of the industry due to the 1962 amendments to the Federal Food, Drug, and Cosmetic Act

2. The effect is illusory because only ineffective new chemical entities have declined
3. A depletion or research opportunities
4. The thalidomide incident caused doctors and firms to be more cautious
5. Costs have risen as a result of advances in the technology of safety testing.

Their conclusions are that while costs in the US rose, costs in the UK which are not affected by the 1962 amendments also rose significantly. This means that there may be a depletion of research opportunities, but there is another force causing the decrease in introductions in the US. These authors fail to capture the causes of the rising prices and falling number of new chemical entities, but do show empirically that this is occurring. Since ceteris paribus is violated by the uses of the chemical entities and the technology used to create them, the analysis becomes more difficult. This paper is useful in my research as support for the theory that new chemical entities become more expensive to produce, after adjusting for inflation, in later years.

Cockburn, and Henderson write in *Scale, Scope, and Spillovers: The Determinants of Research Productivity in Drug Discovery* (1996) that larger pharmaceutical companies enjoy economies of scale and also economies of scope due to knowledge spillovers. A firm with intellectual property and human capital can use these in the research for a greater number of drugs or technologies than a smaller firm. This means that a larger corporation can more cheaply produce drugs thanks to better access to cheap information, marketing, capital, and equipment. This research is especially important in my analysis

of acquisitions. An acquisition or asset purchase may occur due to the purchaser's greater perceived potential profits. These greater profits stem from the lower costs associated with economies of scale and scope.

Turning to contracting, there two seminal papers on the efficiency of contracting. Ronald Coase claims in *The Nature of the Firm* (1937), that contracting is due to transactions costs. He relates this to the purchase of fisher body by GM. Klein, Crawford and Alchian add to the theory in *Vertical Integration, Appropriable Rents, and the Competitive Contracting Process*, 1978. These authors write that a contracting firm may be used rather than independent workers because the firm fears it will be cheated via a hold up. Klein calls this "post contractual opportunistic behavior." Klein claims this is the reason GM bought Fisher Body. Both cases are useful in my evaluation of contracting in a strategic alliance with asymmetric information.

DATA

The data analyzed in this paper was collected from Deloitte Recap LLC (Recap.com, 2007). This is a subscription website that owns a proprietary, searchable dataset comprised of press releases about pharmaceutical alliances. I read through the press releases to obtain all public information on these alliances. Recap designated each alliance as a co-development, license, acquisition, outsource, asset purchase or distribution based on the information available. Each firm was designated by Recap as large pharmaceutical, biotech, or university. The dataset consists of 270 pharmaceutical deals. These deals span the five years of January 2003 to December 2007. The data are only for the following diseases; diabetes, cardiovascular, and respiratory related drugs and technologies. I have only included deals for which some financial information about the deal was made available.

Financial data on the firms was gathered from the press releases, Google Finance, Yahoo Finance, and CRSP and Compustat. The financial data of publicly traded firms is required by the Securities and Exchange Commission to be made publicly available. Market cap was found by multiplying stock price by number of shares. When obtaining this data, many stock prices were available for the day that the deal took place, but some were available monthly. In these cases, the closest date available was used. Some privately owned firms may have some information available such that firms or investors have information signaling the viability of current and future investments in that firm. In the cases in which a firm is acquired, information about the price paid for that firm will

sometimes be available. Although the firm may have been acquired at a premium or discount, the price paid is usually the best indication available of the value of that firm. In many cases, no data was available concerning the market cap of private firms, so these data are treated as missing.

Firm types are described in this paper as *researcher* and *client*, or *purchaser* and *acquired firm*. The researcher is the developer of the drug or technology in the early stages of development, and in every case except an outsourced research deal, is the owner of the intellectual property. The client in these cases is the firm which pays the researcher for rights to the intellectual property being developed. In the case of acquisitions, the firms are described as purchaser and acquired firms, rather than researcher and client.

There are several types of payments used in these pharmaceutical alliances. These are not mutually exclusive payments, so may occur alone or together. The client will contract using these payments to prevent moral hazard and align the incentives of the researcher with its own. The researcher, if it owns the intellectual property (IP), will attempt to sell its intellectual property for economic profit after accounting for cost of capital and drug-specific risk.

The types of payments paid by the client to the researcher are organized as equity, royalty, milestone, research, and upfront payments. *Equity* is a purchase of ownership in

the researcher. Equity is a share of a firm, and in the case that equity in the researcher is purchased, the equity provides the client with some profit sharing in successes of the researcher, and the researcher with capital. *Research* payments are cash payments by the client to the researcher in the case that the client owns the intellectual property, but wishes to outsource some of the research work to another firm. *Upfront* payments are cash payments from the client to the researcher without contractual conditions being met. *Milestone* payments are payments by the client to the researcher in exchange for contractual requirements being met. *Royalty* payments are payments by the client to the researcher to provide the researcher with a residual claim on the product being produced. *Acquisition* payments may consist of cash payments and payments in terms of shares of stock of the acquiring firm. These payments are separated from other types of payments as acquisition payments.

In this study, five types of deals are evaluated; license, asset purchase, co-development, outsource and acquisition[1]. These deal types are mutually exclusive. *Licenses* are the purchase of the use of a specified drug or technology, whether exclusively or non-exclusively licensed worldwide or in a geographic region. Licenses usually mean that some ownership rests with the original holder of the intellectual property. An *asset purchase* is the purchase of a product or group of products, which could be drugs, technologies, or other capital. No ownership rests with the seller in this case, so this is an outright purchase. *Co-development* is an effort between two firms which involves

[1] Of the 270 deals, there were 8 deals that did not fit into these five categories.

payments from the client firm to the researcher, and transfer of some of the intellectual property rights from the researcher to the client. An *acquisition* is the purchase of all equity of a firm. *Outsource* is a deal for which the intellectual property holder outsources some work to another firm, usually in exchange for cash or milestone payments. Outsource is a special case in which the client is the intellectual property holder.

One of the characteristics of the deals involves the stage of development of the research. The Food and Drug Administration (FDA), imposes strict controls on the development and testing of new pharmaceuticals to ensure safety and efficacy. It is important to understand the course that a drug or technology follows during the development and testing phases. On average, it will take 10-15 years for an experimental drug to get from the lab to patients. One out of five thousand compounds make it to human testing from preclinical testing. Of these, one in five is approved for sale. This process costs, on average, 802 million dollars per new medicine (Tufts, 1998).

The first step is preclinical testing, which involves laboratory and animal studies. The specific stages include formulation of new compounds, determining a lead molecule, and discovery of a potentially usable new drug. This process takes about 6.5 years. After this, an investigational new drug application (IND) is filed at the FDA. If the FDA does not disapprove of this IND within 30 days, the IND becomes effective.

The second step is clinical trials. The phase one and two trials take about 1.5 and 2-3 years, respectively, and involve a few healthy and few patient volunteers. Phase three takes about 3.5 years, and is much more expensive to undertake, and includes a large number of patient volunteers to confirm effectiveness and monitor possible long term adverse reactions (PhRMA).

If all of these phases are passed, the firm requests a New Drug Application (NDA) or Biologic License Application (BLA). A BLA is used when the new formulation is a therapeutic DNA plasmid product, therapeutic synthetic peptide product of 40 or fewer amino acids, monoclonal antibody product for in vivo use, or therapeutic recombinant DNA-derived product (FDA, 2008). The firm gathers all of its information, sometimes 100,000 pages or more, and submits this to the FDA, which analyzes the information over the period of about 1.5 years. If the FDA approves the NDA/BLA, the drug is approved, and may be available for physicians to prescribe. The producing company must continue to run tests and send periodic reports to the FDA.

CONTRACTING

The maintained hypothesis of this paper is that firms do not always have the most cost effective means to fully develop a new drug or technology from start to finish. A firm that has initiated research or development of a new drug could attempt to continue development on its own by using its own resources, obtaining capital privately from venture capitalists, incurring debt, or publicly by selling shares of equity. The other option is to enter into an agreement with another firm, which could include continuing the development as an alliance, selling the existing assets, or being acquired completely. The decisions made will be based on the likelihood of success of development, the cost to the researching firm of acquiring capital, and the cost of information gathering and monitoring of the researching firm. If a contract is made, the contract will consist of a nexus of payments which attempt to align the incentives of the client and researching firm.

Table 1 shows the possible observations at each stage of an alliance. The IP owner and the cost of capital of the firms involved are taken as exogenous. After this, timing can be predicted by the model set up in this paper. The model then predicts type of deal from the timing, and payment types from the deal type.

Table 1 – Data Observations							
IP Owner		Cost of Capital		Timing of Deal		Type of deal		Payment Types
Researcher or Client		High or Low		Early or Late		Acquisition, or Outsource, or Co-development, or Asset Purchase, or License		Equity, Royalty, Milestone, Research, Upfront

It is first important to note the owner of the intellectual property. If the researcher owns the intellectual property (IP), then some part of the IP will be sold to the client as part of the deal, and financing will be provided to the researcher. If the client owns the IP, then it is likely that the client is outsourcing some of the research to the researcher. This type of deal is referred to as an outsource deal. I do not have information on the IP owner, so I assume that an outsource deal is due to the client owning the IP.

The model proposed in this paper predicts that the cost of capital is a strong predictor of the timing of deals. Aghion and Tirole (1998) wrote that in a human capital intensive industry such as biotechnology, the large firms will purchase research from smaller firms which have a comparative advantage in production. The large firms, with cheap access to capital, are the buyer of research, and the biotechs specialize in specific areas. The large firm, thanks to large amounts of financial capital, has a comparative advantage in organizing the smaller firms, and marketing and distributing the products once they have

been approved by the FDA. A small firm with very little capital to invest into the development of a drug (Lerner & Merges, 1998) should therefore be interested in forming a strategic alliance with a larger firm that can cheaply acquire capital, as well as the larger firm being interested in acquiring the IP from the smaller firm.

Shirking costs are associated with all contracting arrangements and are come into play in the decision to form a drug development alliance. The larger firms are interested in doing business with the smaller firms partly because shirking costs are reduced when a smaller, more efficient command and control exists. Fewer managers and better alignment of incentives creates a more efficient system of production. In franchising of stores, much like the outsourcing of research explored in this paper, we see large firms passing control to individual owner-operators. The firm expects that the increase in efficiency and subsequent high royalty payments received will offset the forgone profits from operating the store directly.[2]

Monitoring costs (Barzel, 1982) are the costs of overseeing work done by another firm. In the case of strategic alliances, a large part of this monitoring cost will be measurement of the value of production of the researcher firm. The researching firm may also take payments, but not expend resources to produce a valuable product, thereby creating a moral hazard problem. Payment types may be selected for the contract in order to reduce

[2] (Kaufmann & Lafontaine, 1994), (Klein, Crawford, & Alchian, 1978) (Mathewson & Winter, 1985) (Rubin, 1978)

monitoring costs, such that the researcher has incentive to reduce shirking and produce a valuable product. Monitoring costs may also be reduced by selling equity to a single buyer or creating an alliance with a single buyer such that only a single buyer must expend resources to monitor the researcher (Brealey & Myers, 1991).

The value of a product may differ by firm. In the case that neither firm has capital, monitoring, or shirking cost advantages, a deal may occur due to differences in value of the product. This means that the product maybe sold or licensed to the highest valuing firm to profit both firms. This will maximize the value of the IP. The transfer of the IP may be motivated by the gain or loss of human capital, such as the gain or loss to the firm of a scientist or group of scientists. In a simple example, a group of diseases specific specialists may be hired to a small firm and away from another small firm. The small firm that acquired the human capital may choose to license or purchase an IP from the other firm in order to continue research in the area in which it now has a comparative advantage.

The previous few paragraphs have explained that the characteristics of drug development alliances will be driven by cost of capital, difference in value of the commercial potential of the research, and the contractual issues of shirking and monitoring. The next several sections of this paper will describe how these costs lead to the formation of the timing of the deal, type of deal, and payment types used in the deal.

Contracting- Prediction of Timing of Deal

The timing of deals will be driven by cost of capital, monitoring costs, shirking costs, and differences in value. To further analyze this by client and researcher type, Table 2 depicts where we can expect to see deviations in these costs between small and large clients and researchers that drive the timing of the deal.

Table 2 - Analysis of Cost of Capital, Monitoring Costs, and Shirking for a Small Researcher and Large Client	
Early	Cost of Capital; low for client, higher for researcher than in late deal Monitoring; early deal occurs if monitoring and measurement costs are low for client Shirking; low for researcher, high for client
Late	Cost of Capital; low for client, lower for researcher than in early deal [3] Monitoring; late deal will occur if monitoring and measurement costs are high for client Shirking; low for researcher, high for client

Early deals are driven by cost of capital, monitoring, and shirking costs. When the researcher is the IP owner, during any point in the development process, the researching

[3] Although cost of capital is noted as "high" for researcher, and "low" for client in both early and late cases, it is of note that this is a sliding scale such that the researcher is expected to have a high cost of capital if engaging in a late deal, but not as high as will be observed if the researcher engages in an early deal.

firm may decide to sell the existing assets, be acquired, or take on a partner in the development. Taking on a partner requires the small firm to sell some of the IP. This leaves the small researcher with a smaller investment at risk of loss, but smaller profits in the case of a success. When the small researching firm finds it more profitable to sell some IP in exchange for operating capital rather than attempting to borrow the capital, the model predicts that an early stage strategic alliance will be observed.

In addition to easy access to financial capital, larger firms enjoy economies of scale in manufacturing, and economies of scope in distribution and marketing. Having the avenues already set up, larger firms can more cheaply add another drug to the market. In this case, these two firms could form a symbiosis to cheaply and profitably create a new product by specializing in the area in which they have a comparative advantage.

Monitoring costs of the researcher by the client are described as high when the output of the researcher is costly to measure. This problem creates incentive for the client to contract a payment structure that induces the researcher to monitor itself. If it is too costly to measure the product or create a contract, the client may choose to wait until later stages of development to make a deal, in which case the value of the product will be easier to measure. Relative to other deals, ceteris paribus, one for which an early deal is observed has lower monitoring costs

Shirking costs are lower for the small researcher than would be the case, ceteris paribus, for a large researcher. Internal monitoring is less efficient when performed by salaried managers or managers with a small residual claim to a large firm, than by managers with a large residual claim of a small firm or owner operators. This is because the marginal benefit of an hour of work is higher to the worker when that worker owns a larger residual claim (Alchian & Demsetz, 1972).

Late deals are also driven by cost of capital, monitoring, and shirking costs, but the model predicts a late deal to occur between small researcher and large client in the case that the small researcher has a higher market cap relative to other small researchers, or measurement of the product is costly.

The size of the researcher carries more information than simply small or large. A very small researcher is predicted to seek an alliance much earlier than a relatively large researcher. Even in cases that the researcher is relatively small when compared to the client, the researcher's cost of capital may be low enough to support development into late phase testing before taking on an alliance with a client that has a comparative advantage in marketing and distribution. This paper will develop a model that will predict likelihood of an early deal compared to a late deal based on market cap, which is an instrumental variable for cost of capital.

Measurement costs of assets are lower in later stages. If the deal occurred in a late stage, that may be a signal that the cost of evaluating the product in an early stage was higher than the benefit of doing so, so the client chose not to invest until evaluation became less expensive. There may therefore be a correlation between late stage deals and higher monitoring costs, although the late stage deal is not the cause of high monitoring costs.

Deals for which there is not a small researcher and large client will be driven due to a difference in value of products by the two firms. A small researcher, small client deal will happen early if it is an outsource deal, or late if there is a transfer of assets or licenses due to a difference in value of the assets between the two firms. It is plausible that a small firm will buy a license from another firm, regardless of the size of that second firm, if that license is necessary to complement or complete development of a pipeline drug.

For a large researcher and large client deal, the transaction takes place due to the differing valuation of the asset between the two firms. The difference in value may stem from the differing use of the drug. In the case that a researcher has found a new use for a molecule or technology that has been patented by another firm, the researcher will acquire or license the IP to use for the new indication. Most other cases will involve the researcher using the IP to complete a pipeline drug or technology.

If the sizes of the large client and large researcher are relatively similar, there will not be a large enough difference in cost of capital to cause a deal. Due to the lack of substantial

difference in cost of capital, the model predicts that the researcher will not take on an early deal. The researcher will complete the development and testing of the product, and will engage in a late deal if offered a price for the asset or a license which is estimated to result in economic profit.

Contracting – Prediction of the Type of Deal

The above analysis predicts the timing of deals. The model predicts that the type of deal will be determined by the timing of the deal. An early deal will involve higher monitoring and measurement costs due to asymmetric information and high likelihood of failure of the product. The contract created for an early deal will involve a structure and payment types that align incentives and lower monitoring costs. Late deals will involve products which are easier to measure. These late deals will have a contract structure that is oriented towards cash payments to transfer the ownership of an IP rather than incentive alignment and monitoring.

Outsource deals are deals in which the client owns the IP, and is outsourcing research to firms that have a comparative advantage in its production. These deals usually happen early, but can happen early or late and are easy to measure and monitor. In this case, it is arguable that the timing of the deal, the deal type, and the payment type are determined simultaneously by the client.

Co-development deals consist of two firms investing resources into the joint development of a product. The cause of this type of deal is the high cost of capital faced by the researching firm. A very high cost of capital, as discussed in the previous section, may cause the strategic alliance to occur early. An early strategic alliance, if not an outsource deal, is a deal in which the client provides funding and the researcher completes early stage development, which is called co-development. It would be illogical to purchase the asset in the early stages, since the researcher owns the human capital which is producing the asset, and the smaller size of the researcher indicates lower shirking costs, so lower costs of early stage development.

An asset purchase is the outright purchase of another firm's human or physical capital, drug, or technology. The seller maintains no residual claim. This product is likely to be approved or near approval, since it would make more sense to co-develop if the product were in early stages. The purchase may also be of a firm's entire series of drugs or technology, which we cannot describe as "early" or "late" since there are varying degrees of completion of pipeline drugs and technologies. If another firm is already producing products like it, or already have avenues of production set up, the purchasing firm may achieve economies of scale and produce with lower cost. The purchasing firm may also be able to market the product with other products like it, thereby achieving economies of scope.

In the case of a license, the seller maintains some residual claim. The seller receives some payment in exchange for the buyer to use or sell a drug or technology for a specific indication or in a specified geographic market. These products are approved or near approval. Like asset purchases, it would make more sense to co-develop if the product were in the early stages. The buyer may be any size firm, using the drug or technology to complete their product or use it for a different purpose than it is currently approved. The seller may receive royalties on sales as the residual claim. These royalties provide the seller with incentive to maintain the value of the license. By selling a license rather than an asset purchase, the seller maintains some rights and may continue development of the licensed drug or technology, and re-license an improved version.

Klein, Crawford, and Alchian claim that when one firm has invested resources, in this case the client, there is the potential for a hold-up, which they call "post contractual opportunistic behavior." In an attempt to minimize risk of loss through this type of problem, the client will contract with payment types that minimize monitoring costs, and align incentives between the two firms. Table 3 shows which payments we are likely to see given both timing and deal type.

Contracting - Deal Type Determines Payments Types

The model predicts that payment types are determined by deal type. Because the model predicts that the deal type is determined directly by the timing of the deal, and the timing is determined by the cost of capital and monitoring costs, all of these attributes are

captured when predicting payment type. All deals involve the transfer of some monetary asset for some intellectual property or services. Acquisitions are made up of payments from the purchaser to the acquired firm for the acquired firm's assets. The payments can consist of cash or equity in the acquiring firm. These are called acquisition payments in this paper. Because these payments are used in every acquisition and there is no associated timing with acquisitions, the analysis of acquisitions is treated separately. Similarly, outsource deals involve some cash payment generally on a periodic basis over the life of the research contract. These payments are designated as research payments.

For co-development, asset purchases, and license agreements, I expect that there will be some payment upfront, and for co-development and license agreements, some payment through the life of the contract. When the upfront payment is cash paid at one time, and is not a research payment, I call the payment upfront. For some deals, the client will buy an equity share in the research firm for an upfront payment of cash. I call these payments equity. For many of these deals, these payments will be extended over the life of the contract. One way this is designated in the financial press is by the use of the word milestone payments. These are payments that are made when certain events occur in the development of the IP. I label these payments as milestone. Alternatively, for some deals, the extended payments will take the form of royalties on the sale of the IP to users. I call these payments royalties. Table 3 displays the type of payments predicted to be used, the reason for their use, and the timing in which they are expected to be observed.

Table 3 - Payment Type by Type of Deal					
	Acquisition	Outsource	Co-develop	Asset Purchase	License
Early	Acquisition Payments	Research payment[4] (*Generally early*)	Equity[5], Milestone[6]	Upfront	Upfront, Royalty
Late			Royalty[7], Upfront[8], Milestone		

Outsource deals are deals in which the client owns the IP, unlike other deal types, and outsources research to another firm that can perform it more cheaply. This is low-level work for which the value is relatively easy to measure, so cash payments can be made upfront.

Early deals in which the researcher owns the IP, but has a high cost of capital, are predicted to be co-development deals. These deals are the exchange of early financing to the researcher for late phase IP to the client. In this type of early deal, there will exist a high cost of measurement of the product being produced, and a high risk of failure of the product. Equity purchases are likely to occur in this case. The equity purchase allows

[4] *Research* payments are cash payments by the client to the researcher in the case that the client owns the intellectual property.

[5] *Equity* is a purchase of ownership in the researcher.

[6] *Milestone* payments are payments by the client to the researcher in exchange for contractual requirements being met.

[7] *Royalty* payments are payments by the client to the researcher to provide the researcher with a residual claim on the product being produced.

[8] *Upfront* payments are cash payments from the client to the researcher without contractual conditions being met.

the investing firm to share profits without incurring prohibitive measurement costs (Barzel, 1982), and without being able to accurately estimate the value of the product being developed ex ante. Any profitable technology or product that results from the investment will benefit the investing firm.

In co-development deals for which the client is able to more easily measure the product, milestone payments will be used to monitor the researcher's progress. Like equity and royalties, milestone payments provide monitoring through financial means. The researcher is contractually obligated to meet specific goals to receive payment, and may be punished if it fails to do so. Milestone payments may be used in early or late deals as a source of monitoring and financing. As the financing is a prize for completed work, rather than an upfront payment to provide the work, milestones are likely to be used as a complement to another type of financing such as equity or upfront payments. If the goals are met, the milestones are paid to the researcher. If the researcher fails to produce research in a timely manner, the contract stipulates a punishment.

For later co-development deals, or for co-development deals that involve an easily valued product, equity payments may be replaced by royalty and upfront payments. Royalty payments, like equity payments, are intended to resolve problems associates with asymmetric information. Royalty payments, however, are specific to a single product, rather than all products of a firm, so will be more profitable to the researcher than equity payments in the case that the product is a success. The researcher receives a residual

claim to the product, and therefore gains incentive to ensure its viability in the marketplace. This effectively lowers the costs to the client of measuring the value of the product and monitoring the researcher in the face of asymmetric information.

Upfront payments may be required by the researcher in a co-development deal in addition to some combination of royalty, milestone, and equity payments. Upfront payments are cash payments without the contractual obligation associated with milestone payments. This is guaranteed payment to the researcher, usually supplied to the researcher only in the case that the product is late in development. It is therefore easier to value and has a low risk of failure.

In co-development deals, the contract usually stipulates that the ownership of the intellectual property reverts back to the researcher if the client fails to make progress in testing, development, and production. This provides incentive to the client to continue development in a timely manner. Timely production is valuable to the researcher, since the researcher may receive royalties or some revenue stream upon manufacture and sale of the product.

Asset purchases are purchases for which no residual ownership rights are left with the seller. These deals are therefore predicted to be paid in cash. In the case that milestone payments are used, a contract exists that requires the researcher with a nearly complete asset to complete the asset before ownership transfer.

The licensing of a product is the purchase of some rights, but a residual claim rests with the seller. Licensing of a product involves some asymmetric information, as the producer of the license may own the human capital that produced the IP. The patent life of the product may be difficult to measure by the client, such that a license involving profit sharing will be preferred to a cash payment. The client will therefore be faced with incentive to incorporate payments that reduce monitoring and measurement costs. Royalty payments leave a residual claim to revenues with the researcher, providing the researcher with incentive to create a valuable product. Upfront payments will likely also be required by the researcher as a source of upfront financing to recoup expenses and finance future endeavors.

Contracting – Acquisitions

As an alternative to co-development or an asset purchase, a larger firm may decide to acquire a smaller firm. The chance of an acquisition increases if the larger firm wishes to buy a pipeline or the human capital to either create a new division in its own firm or fill a gap in its production line. Purchasing the assets and pipeline of a smaller firm may be cheaper than attempting to co-develop with the firm and monitor their actions. An acquisition can also reduce monitoring costs in the interest of maintaining the value of the patent which was purchased or developed with another firm. If the human capital is not absorbed, there is a chance that the smaller firm will create a patent that trumps the previous patent bought or co-owned by the larger firm.

The larger firms are more likely to have multiple uses of the technology acquired. The technology may improve the production or application of several products, rather than the relatively few for which it was designed by the acquired firm. These multiple uses create economies of scale for the acquiring firm.

The model I set forth here predicts that smaller firms, with their higher cost of capital, will be acquired by relatively larger firms. Acquisitions are the purchase by one firm of all equity in another firm. This purchase can be completed with the buyer paying by cash or by transferring equity from the acquiring firm to the owners of the acquired firm, or some combination of these payments. These cash and equity payments are referred to as "acquisition payments" throughout the paper, so as not to be confused with equity payments from the client to the researcher. Because of the difference in payment structure and there being no phase of testing associated with acquisitions, these deals are analyzed separately from all other deal types.

ANALYSIS OF THE DATA

In the following few sections, the data is analyzed in the same order as discussed in the previous sections. First, summary data is introduced. After this, the timing of the deal is analyzed as a function of researcher market cap. Next, the type of deal is analyzed as a function of the timing of the deal. The types of payments are analyzed as a function of the type of deal. Finally, acquisitions are analyzed separately as a function of researcher market cap.

Marginal effects from a logistic or multinomial logistic regression are used in many of these tables, as noted in the table titles. The marginal effects were obtained using a code in a statistical analysis program which calculates the average of discrete and partial changes over all observations, rather than computing the marginal effects at the means of the variables. This will be especially helpful when the independent variable is a dummy variable.

Table 4 contains information about deal types by payment types, regardless of whether timing data were available. Table 5 contains data on all timing data known for the deals. There were not timing data for all observations, so the summation of early and late deals for each deal type in Table 5 may not match the total number of deals in Table 4. Table 6 contains the number of times the client and researcher were observed to be a large pharmaceutical firm, a biotech, or a university. Table 7 is a table of deals by partner. This is the number of deals that occurred for each combination of client type and researcher type.

Table 4 - Deal Types by Payment Types							
	Total	Equity	Royalty	Milestone	Research	Upfront	Acq Payment
Acquisition	46	0	0	0	0	0	46
Asset Purchase	39	9	13	10	0	31	0
Co-Development	115	32	58	84	21	72	0
License	55	6	28	28	1	28	0
Outsource	7	1	0	3	3	1	0
Option	2	2	1	1	0	1	0
Distribution	6	0	1	1	0	1	0
Total	270	50	101	127	25	133	46

Table 4A - Deal Types by Payment Types – Early Phase

	Total	Equity	Royalty	Milestone	Research	Upfront	Acq Payment
Asset Purchase	7	3	3	2	0	6	0
Co-Development	71	21	40	52	17	40	0
License	16	1	9	9	1	6	0
Outsource	2	0	0	0	1	0	0
Option	2	2	1	1	0	1	0
Distribution	2	0	0	0	0	0	0
Total	100	27	53	64	19	53	0

Table 4B - Deal Types by Payment Types – Late Phase

	Total	Equity	Royalty	Milestone	Research	Upfront	Acq Payment
Asset Purchase	16	5	6	5	0	14	0
Co-Development	34	10	15	30	3	30	0
License	35	4	17	19	0	20	0
Outsource	3	1	0	2	2	1	0
Option	0	0	0	0	0	0	0
Distribution	3	0	1	1	0	1	0
Total	91	20	39	57	5	66	0

Table 5 - Deal Type by Phase of Testing		
	Early	Late
Asset Purchase	7	16
Co-Development	71	34
License	16	35
Outsource	2	3
Option	2	0
Distribution	2	3
Total	100	91

Notes: Early is before phase 2 testing. Timing is not known for all deals. Acquisition deals are omitted because multiple products are being acquired. Timing for acquisitions is therefore not defined

Table 6 - Deals by Type of Client and Researcher			
Client		Researcher	
Large Pharma	131	Large Pharma	20
Biotech	124	Biotech	247
University	15	University	3
Total	270	Total	270

Table 7 – Deals by Partner			
	Client Pharma	Client Biotech	Client University
Researcher Pharma	15	5	0
Researcher Biotech	114	118	15
Researcher University	2	1	0

Analysis - Timing of Deal as a Function of Size of Firm

The model predicts that the timing of the deal will be a function of the size of the researching firm {Timing(Rsize, e)}. Summary statistics of the market cap of researchers and clients for which timing of the deal is known are presented in Table 8. In Table 9, The tabulations of observations from biotech and pharma researchers and clients and shown for each of the three main deal types. These numbers give some indication of the significance of the results found in Table 11. Table 10 predicts the results of table 11, which presents the results of a logistic regression of market cap on the early dummy variable.

Table 8 - Summary Statistics of Firm Market Cap

	Obs	Mean	Median	Std. Dev.	Min	Max
Researcher Market Cap	102	8538.23	406.13	26602.84	8.68	193854.9
Client Market Cap	112	36402.58	10415.42	58998.25	4.14	339408.6

Notes: These statistics do not include observations for acquisitions, nor observations without timing data. Values are in millions of US dollars.

Table 9 - Tabulation of Observations for which Timing and Market Cap Data are Known.

	Co-development	License	Asset Purchase
Client Pharma	49 (51952.77)	14 (35010.04)	6 (87315.47)
Client Biotech	19 (17072.85)	26 (9212.48)	9 (520.53)
Client Mean	68 observations (42206.91)	40 observations (23659.11)	15 observations (35238.5)
Researcher Pharma	6 (51550.39)	3 (68117.53)	2 (105898)
Researcher Biotech	53 (833.77)	23 (3835.52)	7 (1001.09)
Researcher Mean	59 (5991.39)	26 (11252.67)	9 (24311.51)
Client/Researcher Ratio Mean	121.878	58.926	44.766
Client/Researcher Ratio Range	Min: 0.020 Max: 1182.024 35 observations	Min: 0.004 Max: 435.331 11 observations	Min: 0.015 Max: 223.551 7 observations

Mean market cap in parentheses.

Table 10 – Prediction of Marginal Effects from a Logistic Regression of Client and Researcher Market Cap on Early Dummy Dependent Variable: Early Dummy	
Independent Variable:	
Log Client Mkt Cap (millions of $)	Positive
Log Researcher Mkt Cap (millions of $)	Negative

The model predicts that the log client market cap will have a positive coefficient. This is the prediction that larger client firms will tend to make earlier deals. This is because larger clients should be interested in creating a co-development deal with smaller firms. These larger firms have a lower cost of capital, and can afford the early stage, high risk, high return investments. Later deals are predicted to involve a mix of large and small clients, since some small and mid-sized firms will be interested in licensing and purchasing assets from researching firms. This can be to complete a pipeline or make use of economies of scope of the purchased or licensed technology.

The model also predicts that log researcher market cap will have a negative coefficient. This is the prediction that smaller researcher firms will tend to make earlier deals. These researcher firms act in this way because their cost of capital is higher than the larger firms'. The smaller firms, at some point in development, either fail to acquire new operating capital, or find it too costly. When the marginal cost of acquiring capital exceeds the marginal benefit, the researcher may engage in a co-development deal. It is

of note that the considerations in marginal decision making include firm-specific risk aversion and measurement costs of the value of the product being developed.

Table 11 – Marginal Effects from a Logistic Regression of Client and Researcher Market Cap on Early Dummy

Dependent Variable: Early Dummy

Independent Variable:	(1)	(2)	(3)
Log Client Mkt Cap (millions of $)	0.019 (0.320)		0.039 (0.110)
Log Researcher Mkt Cap (millions of $)		-0.092 (0.000) [a]	-0.142 (0.000) [a]
Observations	112	102	55
Pseudo R^2	0.006	0.122	0.340

Notes: p-values are in parentheses, a=significantly different from zero at the 1% significance level. b= significantly different from zero at the 5% significance level, c= significantly different from zero at the 10% significance level. Any observation for which timing data was unknown was dropped. Acquisition deals were dropped. Only 55 observations simultaneously have data on timing, researcher market cap, and client market cap.

The regressions in Table 11 use all deals for which timing data is known, which excludes acquisition deals. The first regression utilizes log client market cap in millions as the independent variable, which is not very predictive. The second regression uses the log of researcher market cap in millions of dollars. Log market cap was used rather than market cap because the probability of observing an early deal, given a smaller researcher market cap, rises at a decreasing rate.

Regression three combines the independent variables. The number of observations here is only 55 because there are only 55 observations for which both client and researcher market cap are simultaneously known. Results are relatively significant, and Pseudo R^2 is high. The interpretation of the marginal effects result for log researcher market cap is that a 100% increase in researcher market cap will decrease the likelihood of observing an early deal by 14.2% when compared to a late deal. As the client market cap increases by 100%, the likelihood of observing an early deal increases by 3.9%.

The significance of the marginal effects of log researcher market cap are greater than those for log client market cap, and 100% change in researcher market cap has a greater effect on likelihood of observing an early deal than a 100% change in client market cap. These results agree with the model's prediction[9] that an early deal will be undertaken primarily due to the researcher's cost of capital.

Analysis - Type of Deal as a Function of Timing

The model predicts that the type of deal will be partially determined by timing of deal {Deal(Timing(Rsize,e),e)}. A researching firm will choose the timing of the deal based on its own cost of capital. Other factors, such as firm-specific risk of failure, measurement costs, and how the drug or technology being considered will compliment or substitute other drugs, technologies, or pipelines currently help by the client firm, will weigh heavily in the decision of deal type, however these factors are not observed in my

[9] See the explanation of Table 2 and Table 10 for more on this model.

dataset. Because of the importance of some of these missing data, I regress deal type on timing, which is a function of researcher size, rather than simply regressing deal type on researcher size. In this way, I capture some of the factors influencing timing that are not available in my dataset.

Table 12 – Predicted Marginal Effects from a Multinomial Logistic Regression of Deal Type on Early Dummy				
	Dependent Variable: Deal Type			
Independent Variable:	Co-development	License	Outsource	Asset Purchase
Early Dummy	+	-	+	-

Table 12 presents the predictions of the results for the marginal effects from a logistic regression of deal type on the early dummy variable. This is the prediction of deal type based on the observation of an early deal. I expect to observe a positive coefficient for the early dummy when the dependant variable is co-development and outsource. This is because co-development and outsource deals occur early in development of drugs and technologies. There exist two major reasons for co-development deals being likely to occur as early deals rather than late in phase testing. First, the early deals involve products which are more likely to fail before approval than products in late deals, so the type of alliance made between the firms should align incentives in the face of high measurement costs. Secondly, the researcher holds ownership of the human capital that created the product, so it would be more efficient for the researcher to continue early

phase development. A co-development deal allows the researcher to continue development, but transfer intellectual property to the client later in development or testing. The results of the logistic regression should indicate a high likelihood that if an early deal is observed, the deal will be a co-development.

I expect to observe a negative coefficient for license and asset purchase deal types. The client firm will be unlikely to license a product that is in the early stages of development since it is hard to measure the value of the product, and the product is probably not ready for use. Asset purchases are similarly unlikely to occur in early stages, but the client may acquire some early stage products during the acquisition of a pipeline. The other factors that determine whether a license or asset purchase is chosen are attributes of the client firm which are not observed in my dataset. When creating or expanding a division, the client firm may choose an asset purchase of human and physical capital, as well as intellectual property. If completing a product and a patented piece is missing, then the model predicts that a license is more likely.

Table 13 – Average Marginal Effects from a Multinomial Logistic Regression of Deal Type on Timing			
	Dependent Variable: Deal Type (dummy)		
Independent Variable:	Co-development (1)	License (2)	Asset Purchase (3)
Early Dummy	0.355 (0.058)[c]	-0.138 (0.054)[c]	-0.071 (0.157)
Observations	179		
Pseudo R^2	0.071		
Notes: p-values are in parentheses, a=significantly different from zero at the 1% significance level. b= significantly different from zero at the 5% significance level, c= significantly different from zero at the 10% significance level.			

In Table 13 (columns 1-3), the marginal effects from a single multinomial logistic regression of deal type dummy variables on timing dummy variables are shown. Outsource deals were not used because of too few observations. The results, except for R^2, would be identical to four separate logistic regressions because deal type is mutually exclusive. Observations used here are those for which timing data is known and for which one of the three main deal types listed is used.

Observing an early deal indicates an increase in probability that the deal will be a co-development deal by 35.5% (column 1) when compared to a late deal. Observing an early deal decreases the probability that the deal will be a license or asset purchase, compared to a late deal, by 13.8% and 7.1% respectively (columns 2 and 3).

Analysis - Likelihood of Payment Types as a Function of Deal Type

The model now predicts that payment types will be predicted by deal type {Payment(Deal(Timing(Rsize,e),e),e)}. Again, due to the importance of some unavailable data, payment types are predicted from observed deal types, which capture the influence from the error terms from the prediction of timing.

Table 14 – Predictions of Marginal Effects from Logistic Regression of Payment Type Dummy Variables On Deal Type Dummy Variables

	Dependent Variable				
Independent Variables:	Equity	Royalty	Milestone	Research	Upfront
Co-development	+	+ -	+	+	+ -
Asset Purchase	+ -	-	-	-	+
Outsource	+ -	-	+ -	+	-
Early Dummy	+	+ -	+	+	-

Predictions in Table 14 are made against the omitted variables license deals and late dummy. The model predicts that the regression of equity payments on deal type will show that it is more likely to observe equity payments in co-development deals than any other deal type. Equity is likely to be used when the value of the product is difficult to measure ex-ante, so is more likely to be used in early deals, which is more likely to be a

co-development deal. It is difficult to predict whether equity will be used more often in license, asset purchase, or outsource deals. Each of these deal types are not predicted to use equity payments in any systematic way, so significance of the results are predicted to be low.

Royalty payments are expected to be used where the researcher maintains some residual claim. This is most often the case in license deals. Co-development deals also contain a royalty component to give an incentive to produce a viable product. The model presented in this paper therefore predicts that licenses and co-development deals will be more likely to be associated with royalty payments than outsource and asset purchase deals. Since co-development deals are predicted to occur early, and license deals are predicted to occur late, it is difficult to predict a sign for the coefficient of timing.

Milestone payments are predicted by the model to occur most often with co-development deals. Co-development deals tend to be long-term deals which contract production which is costly to measure and monitor. The model predicts that milestone payments tend to be a good contractual tool to reduce monitoring costs. These payments may be used with license deals also, but it is predicted to be seen much less often with asset purchases, which should be associated with upfront payments. Outsource deals may also have a milestone component, but because it is more likely to see a contracted research payment, it is hard to predict whether it is more or less likely to see a milestone component with outsource deals than license deals. It is also difficult to predict whether milestone

payments occur early or late, since these payments can be used with several deal types, but the model predicts that these payments will tend to be early.

Research payments are predicted to be observed with outsource deals more often than any other deal type. These payments are not predicted to be observed with asset purchases, and rarely observed with licenses. Outsource deals occur early, so the early dummy should have a positive coefficient.

Upfront payments are expected to be used in asset purchase contracts more often than co-development, outsource, or license deals. Upfront payments are therefore predicted to occur late. Because the seller maintains no residual claim when selling an asset, there should be no payment which contractually obligates the seller to complete any future work or receive any revenues after the initial cash payment. Because the upfront component of an outsource deal is called a research payment, upfront payments are predicted to occur less often with outsource deals. It is difficult to predict whether co-development deals, or the omitted variable, license deals, are more likely to contain an upfront component.

Table 15 - Marginal Effects from Logistic Regression of Payment Type Dummy Variables on Deal Type Dummy Variables					
	Dependent Variable				
Independent Variables:	Equity (1)	Royalty (2)	Milestone (3)	Research (4)	Upfront (5)
Co-development	0.175 (0.018) [b]	-0.046 (0.574)	0.218 (0.009) [a]	0.154 (0.000) [a]	0.151 (0.041) [b]
Asset Purchase	0.173 (0.131)	-0.162 (0.103)	-0.253 (0.016) [b]	No Obs	0.246 (0.001) [a]
Outsource	0.056 (0.803)	No Obs	-0.070 (0.694)	0.606 (0.000) [a]	-0.399 (0.033) [b]
Early Dummy	0.035 (0.568)	0.129 (0.083) [c]	0.008 (0.912)	0.119 (0.013) [b]	-0.140 (0.043) [b]
Observations	216	209	216	177	216
Pseudo R^2	0.032	0.024	0.102	0.145	0.066
Notes: P-values are in parentheses, a=significantly different from zero at the 1% significance level. b= significantly different from zero at the 5% significance level, c= significantly different from zero at the 10% significance level.					

The model predicts that the payments used in a deal will be a function of the deal type. The five logistic regressions in Table 15 are the regression of payment type dummy variables only on deal type and timing dummy variables. I have included only deals for which the deal type was co-development, license, asset purchase, or outsource, of which there were 216. Some regressions have less than 216 observations in the cases that some

observations were dropped due to perfect prediction of failure (no observations were found for asset purchases and research payments occurring together, or for outsource deals and royalty payments occurring together).

For these five regressions (1-5), I have dropped the independent dummy variable for license deals. Each regression presents the increase in probability, relative to the excluded variable (license deal dummy variable), that the payment type will be observed given that a certain deal type was observed. For example, the cell in the top left shows that if a co-development deal is observed, it is 17.5% more likely that we will observe an equity payment than if a license deal were observed.

The results agree with the predictions of the model. Notable results are that royalties are predicted to occur early, due to so many early co-development deals using royalty payments. Upfront payments are predicted to be used more often with co-development deals than with license deals in this dataset.

Analysis – Acquisitions

The following logit in Table 16 tests the probability of an acquisition occurring. This is done by comparing the attributes of acquisition deals to non-acquisitions deals. The market cap of all firms in all deal types are included here, which is why the number of observations of market cap seen in Table 16 are at most 164, whereas in table 11, I had at

most 112 observations. The fact that 164 firms of each type[10] had information available on market cap is purely a coincidence, and not all of these observations overlap. Only 98 of these observations overlap. The "firm ratio" variable is the ratio of the potential purchaser to potential acquired firm in each individual deal.

In the six logistic regressions of Table 16, I estimate the probability of an acquisition occurring (where the dependent variable, acquisition deal dummy, equals one) compared to an acquisition not occurring (acquisition dummy equal to zero). The marginal effects therefore show the change in probability of an acquisition deal type occurring, given that there is some marginal change in the market cap of one of the firms.

[10] "firms of each type" refers to researchers and clients, which are referred to in the acquisitions section as "potential acquired firms" and "potential purchasers."

Table 16 – Marginal Effects of Logistic Regression of Acquisition Deal Type on Market Cap						
	Dependent Variable: Acquisition Deal Dummy					
Independent Variable:	(1)	(2)	(3)	(4)	(5)	(6)
Potential Acquired Firm Market Cap ($10 billions)	-0.048 (0.154)					
Potential Purchasing Firm Market Cap ($100 billions)		0.043 (0.423)				1.34e-06 (0.058) [c]
Log Potential Acquired Market Cap ($millions)			-0.057 (0.000) [a]		-0.081 (0.000) [a]	-0.090 (0.000) [a]
Log Potential Purchasing Market Cap ($millions)				-0.010 (0.358)	0.004 (0.835)	
Observations	164	164	164	164	98	98
Pseudo R^2	0.017	0.004	0.079	0.005	0.132	0.160
Notes: P-values are in parentheses, a=significantly different from zero at the 1% significance level. b= significantly different from zero at the 5% significance level, c= significantly different from zero at the 10% significance level.						

The marginal effects from the first logit (regression 1) show that as the potential acquired firm's market cap rises by $10 billion, it is 4.8% less likely to be involved in an acquisition, which agrees with my hypothesis. The pseudo R^2 and the significance level are low, however. Logging the potential acquired firm's market cap (regression 3) gives a more significant result and higher R^2, showing that this is not a linear relationship. Adding logged potential purchaser market cap and ratio of potential purchaser market cap

to logged potential acquired firm's market cap (regression 5) brings the R^2 to 0.132. Using potential purchaser market cap rather than logged potential purchaser market cap has more explanatory power, so in regression 6, this is used. Pseudo R^2 is high, and potential purchaser market cap, as well as the logged potential acquired firm's market cap, have significant results. In this regression, we are left with only 98 observations for which all variables are available.

In regression 6, an increase in firm market cap of the purchaser of 100 billion dollars increases the likelihood of observing an acquisition by $13.4*10^{-5}$ %. In Table 17, we see that the largest purchasers are over 200 billion dollars in market cap. With a marginal effect this small, the purchaser's size seems to play a very small role in the likelihood of observing an acquisition deal.

The high significance of the log of the potential acquired firm's market cap in regression 6 is evidence that a very small firm is more likely to be acquired. To be more specific, as the size of the researcher rises by 100%, the probability of observing a firm being acquired compared to not being acquired, but instead some other type of deal occurring, falls by 9%.

Larger firms are less likely to be acquired than engage in another type of deal. There are two reasons for seeing this result. First, it is expensive to acquire another firm, and the larger the firm, the larger the opportunity cost of the capital invested in buying the other

firm. The second reason is that a larger firm is more likely to have several projects going on, many of which the purchaser may not be interested. In the case of a larger researching firm, the client may choose to purchase some specific assets of that firm rather than the entire firm. This is the acquisition of some combination of human capital, physical capital, and intellectual property.

Table 17 - Summary Statistics for Firms Involved in Acquisitions

	Obs	Mean	Median	Stand Dev	Min	Max
Purchaser Market Cap	34	44709.22	13651.19	69341.35	12.759	269621.7
Acquired Market Cap	46	2172.67	85.25	8435.93	1.5	52470.11

Due to cost of capital, it is unlikely that a small firm would acquire a large firm. Of the 46 acquisitions in the dataset, 42 of the acquisitions were of biotechs, and 4 were of pharma. Of those 4 pharma, 3 were acquired by another pharma, and one relatively small pharma was acquired by a relatively large biotech. This is an acquisition of product pipelines and human and physical capital. By acquiring the entire pipeline and all licenses held by the acquired firm, the purchasing firm can ensure that they hold all relevant information and future patents that would be put out by that firm. In the case that the purchasing firm did not purchase the entire firm, but rather an asset from the

firm, the researching firm may have residual research and human capital, providing the ability to create new licenses that trump the old ones. The acquisition of the researcher prevents this hazard. In addition, the purchase of the pipeline may add to the knowledge base of the client firm, creating knowledge spillover.

Large firms may acquire the pipeline and intellectual property of smaller firms to use the technology in multiple sectors of their development programs. Buying another firm's development program for one drug may prove profitable, depending on cost of capital and economies of scope, but this technology may prove useful in other areas of the purchasing firm's production line. In this case, it may be profitable to buy the technology of entire firm. The purchase of intellectual property from another firm may prevent the need to reproduce that research and development in-house. Using a single technology in multiple pipeline drugs or technologies could be compared to the use of one engine or transmission in several cars by General Motors or Ford Motor Company. David Seltzer, President and CEO of Hi-Tech Pharmacal, stated in a press release in Business wire on December 31, 2007, that "This acquisition expands Hi-Tech's product line, broadens our dosage form offerings, brings us into new therapeutic categories, adds to the Company's growing pipeline of products and brings experienced management. We believe that the acquisition will be accretive to earnings and cash flow positive in the first year."[11]

[11] Recap.com, Hi-Tech Pharmacal Acquires Midlothian Laboratories - Dec 31, 2007 – Business wire

CONCLUSION

With a sample of 270 strategic alliances, this research introduces a model to predict efficient contracting of a strategic alliance's timing, payment structure, and organization. The model predicts that the size of the researching firm dictates its cost of capital, and a high cost of capital will induce the researcher to sell the intellectual property sooner than a larger researcher would. The timing of the deal is then used by the model to predict the type of deal that will occur. Co-development and outsource deals will be observed to occur early, while asset purchases and licenses will occur in late deals. The deal type then carries some information about both the nature of the deal and the timing of the deal, so payment types are predicted from deal type. Some combination of equity, royalty, milestone, research, and upfront payments will be used to reduce the monitoring costs to the client.

The model predicts that small researching firms, with high cost of capital, will be inclined to form a co-development alliance with larger firms, which have lower costs of capital but higher shirking costs. The small firm will efficiently produce research, and then sell the intellectual property when the marginal cost of procuring capital has exceeded the marginal benefit. The larger firm will finish late stage development and testing with low cost capital, then take advantage of economies of scale and scope to cost effectively manufacture, market and distribute the product. Larger client firms, with the lowest cost of capital, will be more willing to undertake riskier (earlier stage) investments. Larger

client firms will therefore be observed taking part in earlier deals with smaller researcher firms.

In the case that the product is very hard to measure due to asymmetric information, or the researching firm is very large, the product may not be sold until late phase testing or even after approval. In this case, the deal type is more likely to be a license or asset purchase rather than co-development. The differences between co-development and license or asset purchases are timing of the deal and the payment types used. The payment types used in co-development deals are chosen to align incentives in order to efficiently produce research and development without incurring high monitoring costs. In license and asset purchases, the products are complete or near complete, so monitoring payments are not needed. Cash payments can be used to transfer the intellectual property from researcher to client without leaving a residual claim to the researcher. Paying the researcher a royalty, however, provides incentive for the researcher to provide a valuable product and reduces incentive for the researcher to create a better product, which would devalue the one which was sold to the client.

Acquisitions are treated separately here due to the differing structure of the deal and lack of a timing component. This deal type is used to fill gaps in a larger firm's research pipeline and solve a monitoring problem. In the case that a firm has gaps in its research pipeline, it may choose to buy the pipeline from another firm. This decreases the purchaser's inefficiency of holding idle resources or the buying and selling of human and

physical capital. By acquiring the entire firm, the purchaser acquires all intellectual property and human capital. This ends competition from that firm, decreasing probability that the acquired pipeline will be trumped by a new product. When the researcher is a small firm, it is relatively cheap to buy the entire firm. The analysis in this paper illustrates that a larger researching firm is much less likely to be purchased.

REFERENCES

Aghion, P., & Tirole, J. (1994). The Management of Innovation. *The Quarterly Journal of Economics, Vol. 109, No. 4* , 1185-1209.

Alchian, A., & Demsetz, H. (1972). Production, Information Costs, and Economic Organization. *American Economic Review, Vol. 62, No. 5* , 777-795.

Arora, Ashish, & Gambardella, A. (1990). Complementarily and External Linkages: The Strategies of the Large Firms in Biotechnology. *The Journal of Industrial Economics, Vol. 38, No. 4* , 361-379.

Barzel, Y. (1982). Measurement Cost and the Organization of Market. *Journal of Law & Economics* , 27-48.

Brealey, R. A., & Myers, S. C. (1991). *Principles of Corporate Finance, 4th edition.* Mcgraw Hill.

Center for Research in Security Prices. (n.d.). Retrieved January 2008, from Center for Research in Security Prices Web Site: http://www.crsp.com/

Civan, A., & Maloney, M. T. (2006). The Determinants of Pharmaceutical Research and Development Investments. *Contributions to Economic Analysis & Policy: Vol. 5 : Iss. 1, Article 28. Available at: http://www.bepress.com/bejeap/contributions/vol5/iss1/art28* .

Civan, A., & Maloney, M. T. (2007). The Effect of Price on Pharmaceutical R&D. *Contributions to Economic Analysis & Policy: Vol. 5 : Iss. 1, Article 28. Available at: http://www.bepress.com/bejeap/contributions/vol5/iss1/art28* .

Coase, R. H. (1937). The Nature of the Firm. *Economica* , 386-405.

Cockburn, I., & Henderson, R. (1996). Scale, Scope, and Spillovers: The Determinants of Research Productivity in Drug Discovery. *The RAND Journal of Economics* , 32-59.

Compustat. (2003-2008). Retrieved 2008, from Compustat Website: https://www.compustatresources.com/support/index.html

Danzon, P., Epstein, A., & Nicholson, S. (2004). Mergers and Acquisitions in the Pharmaceutical and Biotech Industries. *The Wharton School, University of Pennsylvania* .

Danzon, P., Nicholson, S., & Pereira, N. (2003). Productivity in Pharmaceutical-Biotechnology R&D: The Role of Experience and Alliances. *The Wharton School, University of Pennsylvania* .

FDA. (2008). *New Drug Application (NDA) Process*. Retrieved January 2008, from U.S. Food and Drug Administration: http://www.fda.gov/CDER/REGULATORY/APPLICATIONS/nda.htm

Finance, G. (2003-2008). Retrieved January 2008, from Google Finance Website: http://finance.google.com/finance

Finance, Y. (2003-2008). Retrieved January 2008, from Yahoo Finance Website: http://finance.yahoo.com/

Galambos, L., & Sturchio, J. (1998). Pharmaceutical Firms and the Transition to Biotechnology: A Study in Strategic Innovation. *The Business History Review, Vol. 72, No. 2, Gender and Business* , 250-278.

Grabowski, H., & Vernon, J. (1977). Consumer Protection Regulation in Ethical Drugs. *American Economic Review* , 359-364.

Grabowski, Vernon, & Thomas. (1978). Estimating the Effects of Regulation on Innovation: an International Comparative Analysis of the Pharmaceutical Industry. *Journal of Law and Economics* , 133-163.

Jensen, M., & Meckling, W. (1976). Theory of the Firm: Managerial Behavior, Agency Costs and Ownership Structure. *Journal of Financial Economics* , 305-360.

Kaufmann, P., & Lafontaine, F. (1994). Costs of Control: The Source of Economic Rents of McDonald's Franchisees. *Journal of Law and Economics, Vol 37, No. 2* , 417-453.

Klein, B., Crawford, R., & Alchian, A. (1978). Vertical Integration, Appropriable Rents, and the COmpetitive Contracting Process. *Journal of Law and Economics* , 297-326.

Lerner, & Merges. (1998). The control of Technology Alliances: An Empirical Analysis of the Biotechnology Industry. *The Journal of Industrial Economics, Vol. 46, No. 2* , 125-156.

LLC, D. R. (2008, January). Retrieved from Deloitte Recap LLC Website: http://www.recap.com

Mathewson, F., & Winter, R. (1985). The Economics of Franchise Contracts. *Journal of Law and Economics* , 417.

Nicholson, S., Danzon, P., & McCullough, J. (2005). Biotech-Pharmaceutical Alliances as a Signal of Asset and Firm Quality. *Journal of Business, Vol 78, No. 4* .

Oi, W. (1962). Labor as a Quasi-fixed Factor. *Journal of Political Economy* , 538–555.

PhRMA. (n.d.). Retrieved January 2008, from The Pharmaceutical Research and Manufacturers of America Website: www.phrma.org

Recap.com. (2007, December 31). Retrieved January 2008, from Delloite Recap: https://www.recap.com/alliance.nsf/fcfd74000f57ac478825648000817cb9/1f9246c8143a97ae882573c20064e199?OpenDocument

Robinson, & Stuart. (2007). Financial Contracting in Biotech Strategic Alliances. *Journal of Law and Economics* .

Rubin, P. (1978). The Theory of the Firm and the Structure of the Franchise Contract. *Journal of Law & Economics* , 223-234.

Tufts. (1998). *Data on drug development, 1994-1998*. Retrieved January 2008, from Tufts Center for the Study of Drug Development Website: http://csdd.tufts.edu/